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(54) Title of the invention: Expanding a tubular member

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(21) Application No:	0404839.3	(72) Inventor(s): Robert Lance Cook David Paul Brisco Bruce R Stewart Lev Ring Richard Carl Haut Robert Donald Mack Alan B Duell
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(43) Date A Publication:	21.07.2004	(74) Agent and/or Address for Service: Haseltine Lake & Co Redcliff Quay, 120 Redcliff Street, BRISTOL, BS1 6HU, United Kingdom
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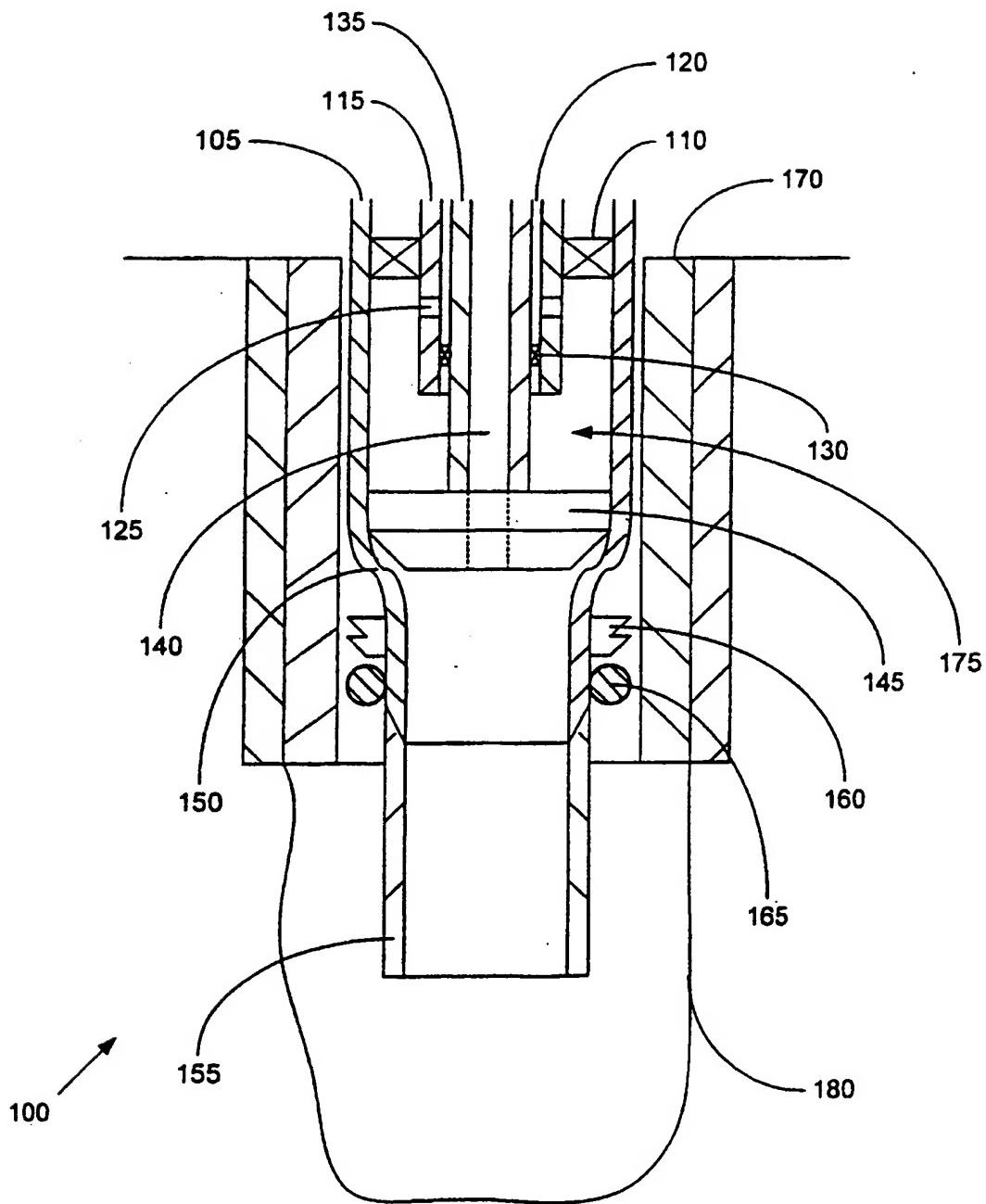


FIG. 1a

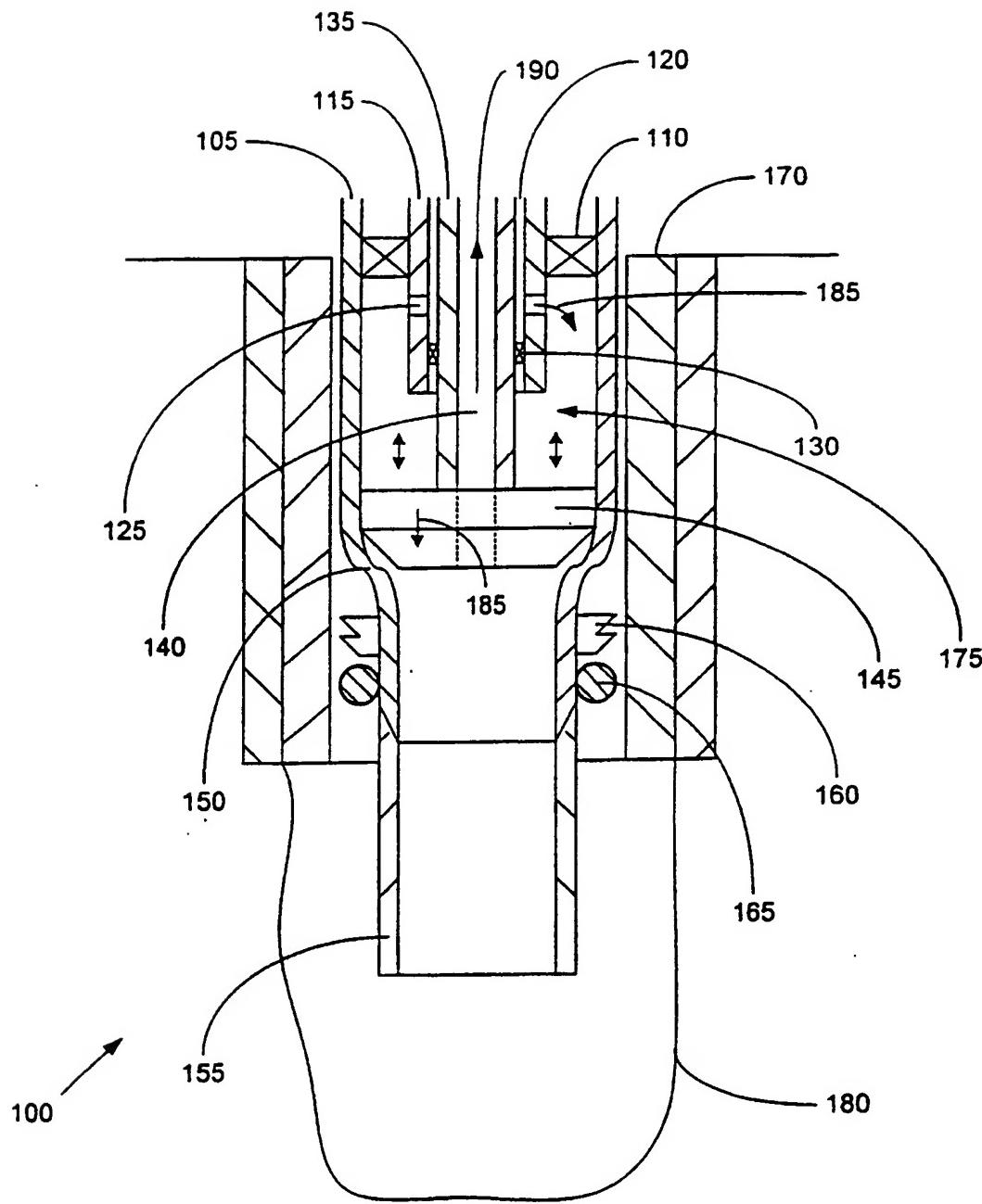


FIG. 1b

3/8

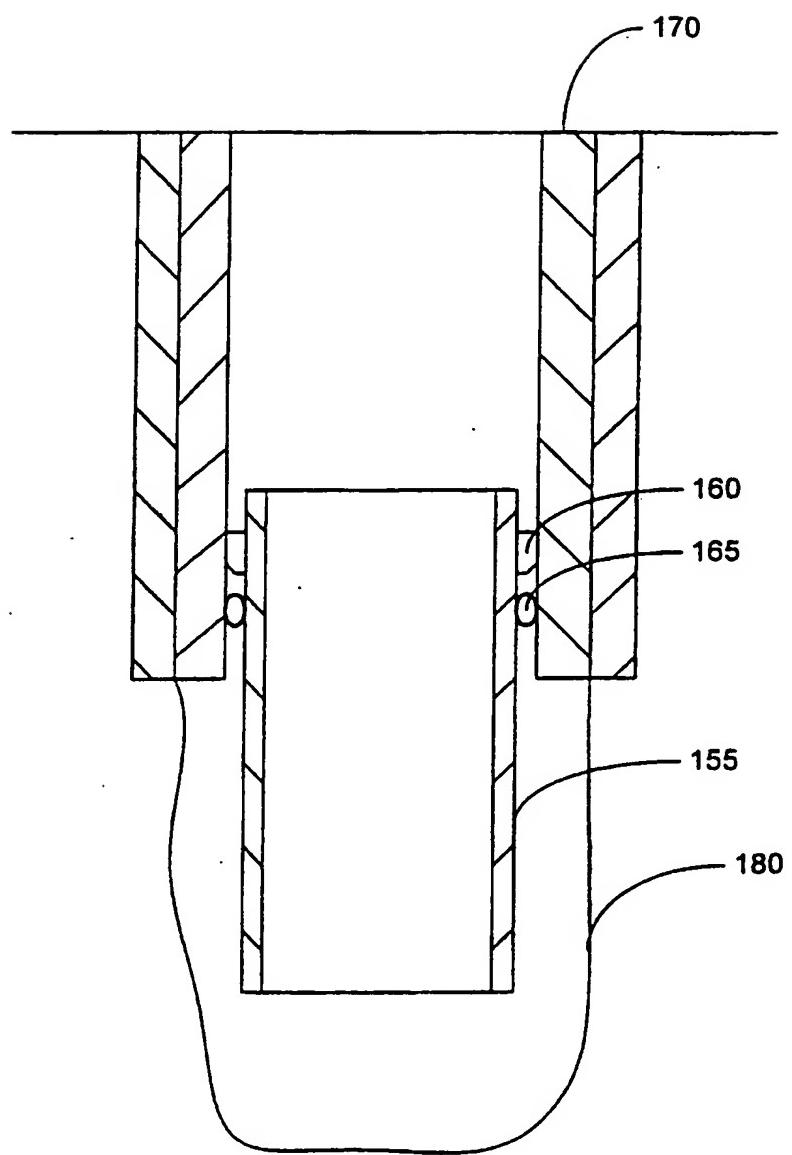


FIG. 1c

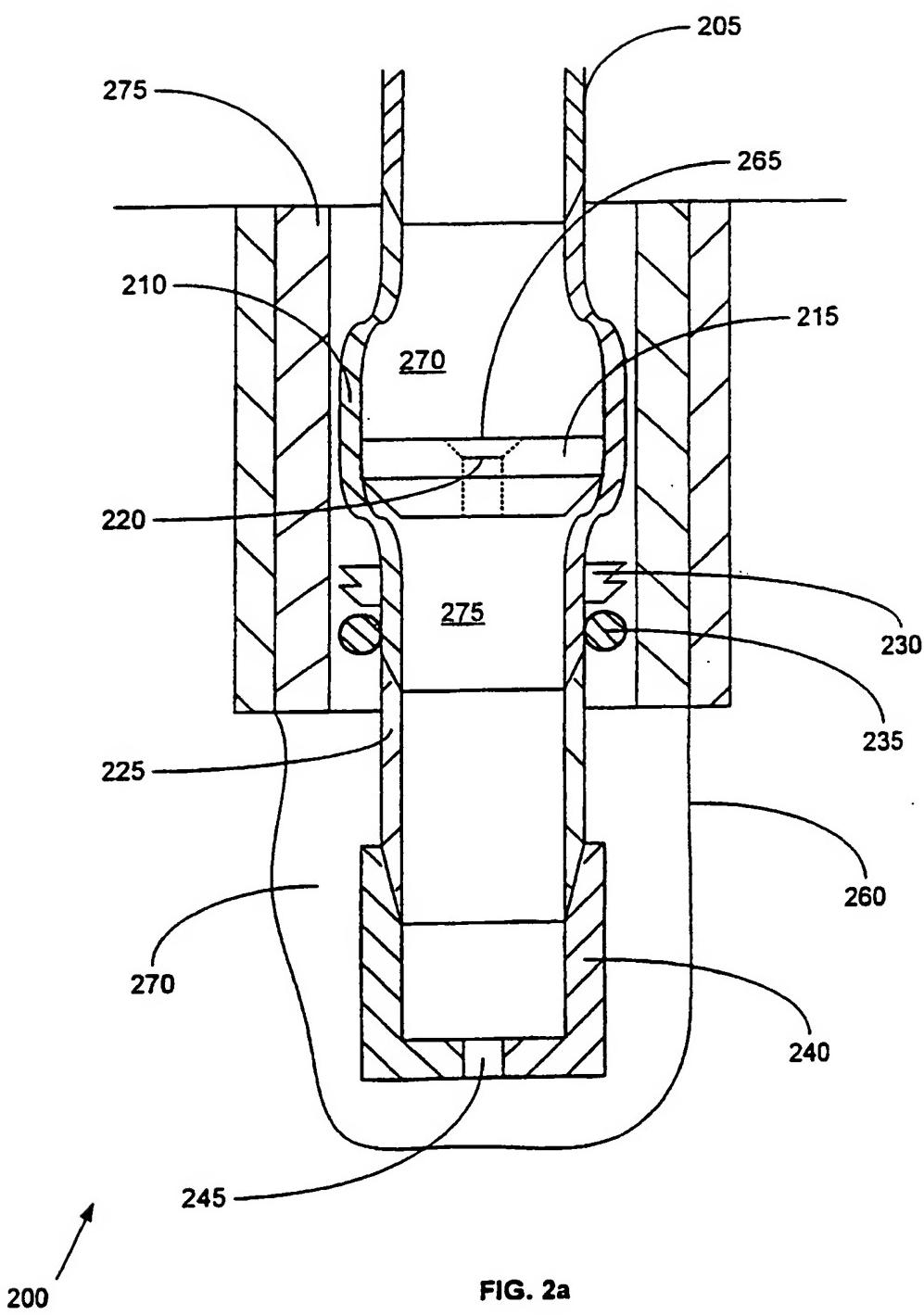


FIG. 2a

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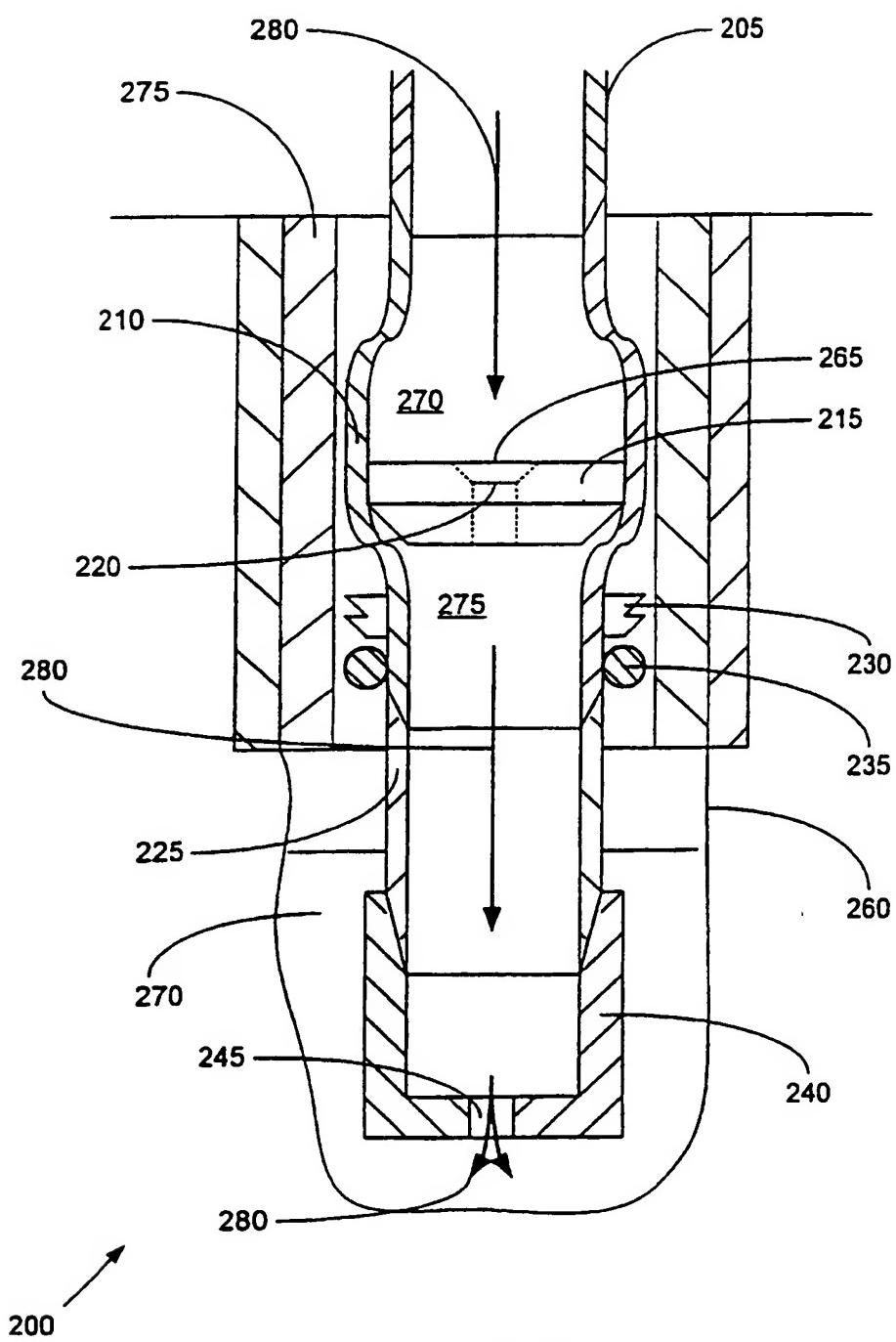


FIG. 2b

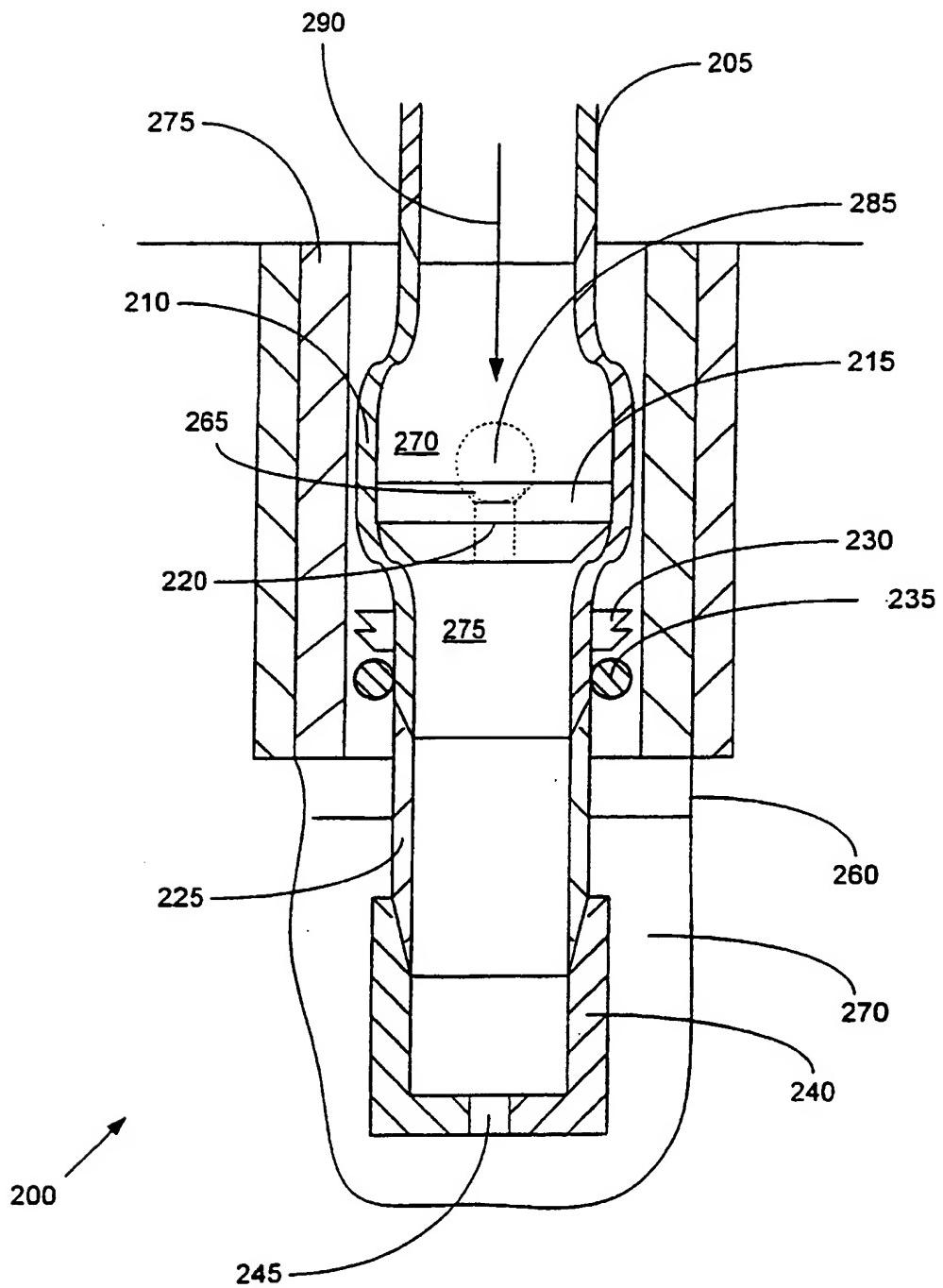


FIG. 2c

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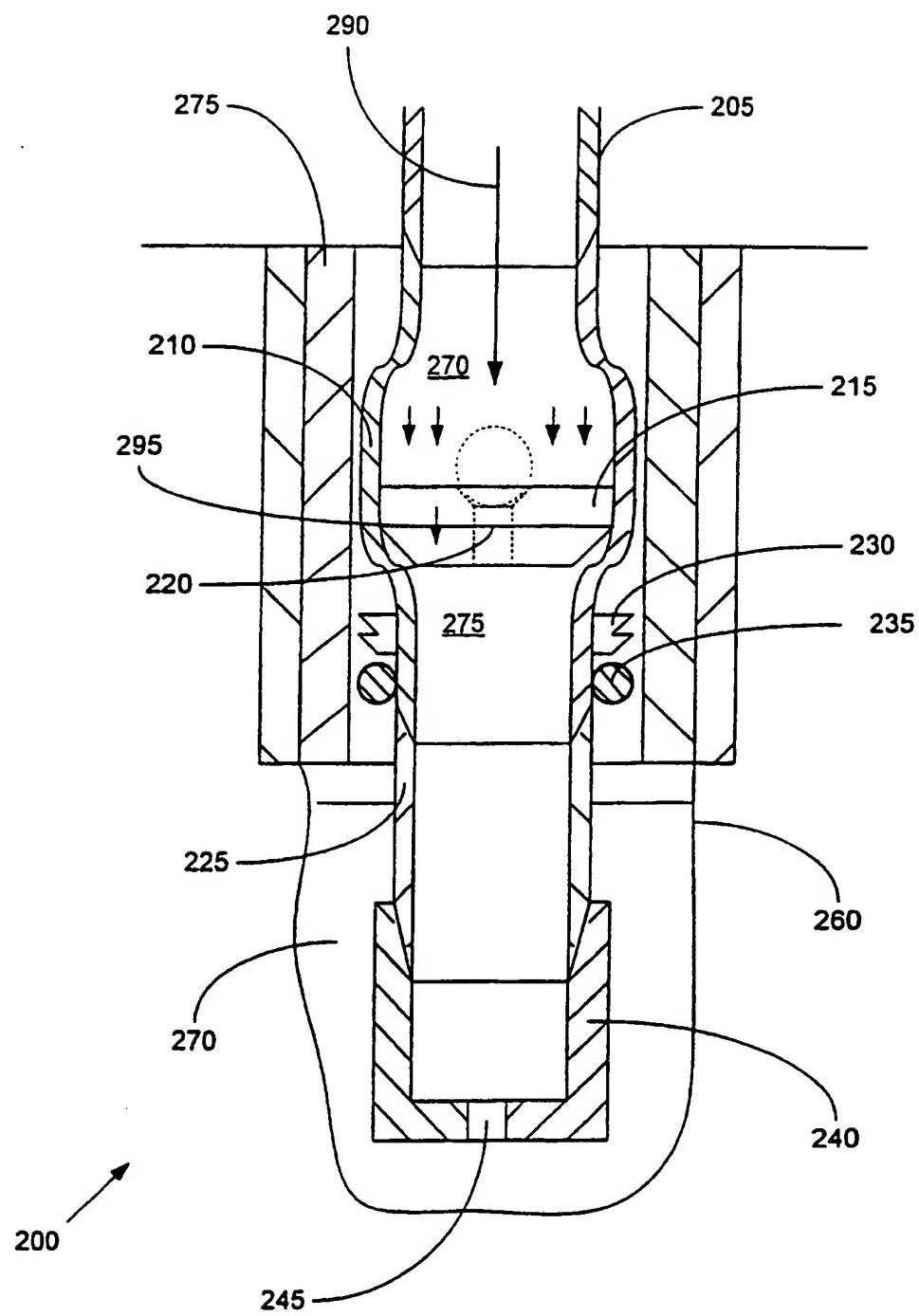


FIG. 2d

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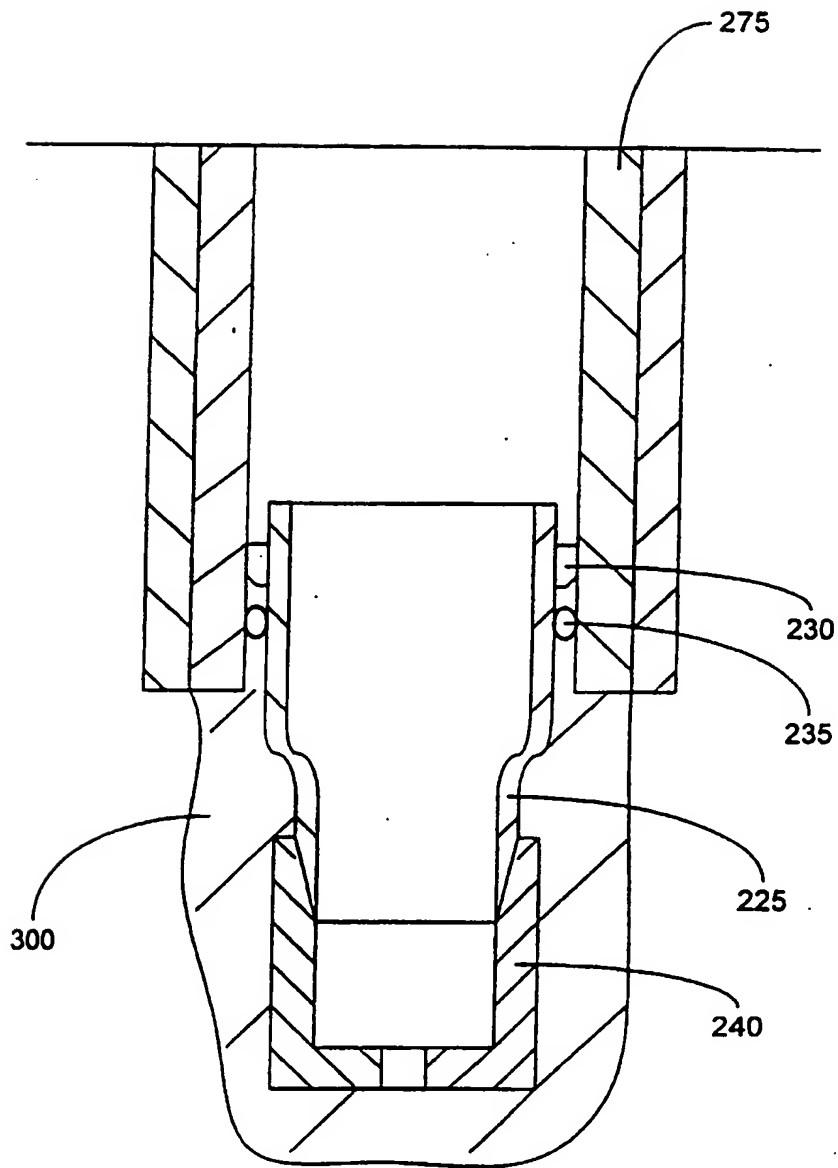


FIG. 2e

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EXPANDING A TUBULAR MEMBER

Cross Reference To Related Applications

The present application claims the benefit of the filing date of U.S. provisional patent application serial no. 60/183,546, attorney docket no. 25791.10, filed on 5 2/18/2000, the disclosure of which is incorporated herein by reference.

This application is a continuation-in-part of U.S. Serial No. 09/559,122, attorney docket number 25791.23.02, filed on 4/26/2000, which issued as United States Patent Number 6,604,763, which claimed the benefit of the filing date of U.S. provisional patent application serial number 60/131,106, filed on 4/26/1999, which was a 10 continuation-in-part of U.S. patent application serial number 09/523,468, attorney docket number 25791.11.02, filed on 3/10/2000, which claimed the benefit of the filing date of U.S. provisional patent application serial no. 60/124,042, filed on 3/11/1999, which was a continuation-in-part of U.S. patent application serial number 09/510,913, attorney docket number 25791.7.02, which claimed the benefit of the filing date of U.S. 15 provisional patent application serial number 60/121,702, filed on 2/25/1999, which was a continuation-in-part of U.S. patent application serial number 09/502,350, attorney docket number 25791.8.02, filed on 2/10/2000, which claimed the benefit of the filing date of U.S. provisional patent application serial number 60/119,611, attorney docket number 25791.8, filed on 2/11/1999, which was a continuation-in-part of U.S. patent 20 number 6,497,289, attorney docket number 25791.3.02, filed on 12/3/1999, which claimed the benefit of the filing date of U.S. provisional patent application serial number 60/111,293, filed on 12/7/1998.

The present application is related to the following U.S. patents and applications: (1) utility patent number 6,328,113, attorney docket number 25791.9.02, filed on 11-15-25 1999, which claimed the benefit of the filing date of provisional patent application number 60/108,558, attorney docket number 25791.9, filed on 11-16-1998; (2) utility patent number 6,497,289, attorney docket number 25791.3.02, filed on 12-3-1999, which claimed the benefit of the filing date of provisional patent application number 60/111,293, attorney docket number 25791.3, filed on 12-7-1998; (3) utility patent 30 application number 09/502,350, attorney docket number 25791.8.02, filed on 2-10-2000, which claimed the benefit of the filing date of provisional patent application number 60/119,611, attorney docket number 25791.8, filed on 2-11-1999; (4) provisional patent application number 60/121,702, attorney docket number 25791.7, filed on 2-25-1999; (5) provisional patent application number 60/121,841, attorney

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docket number 25791.12, filed on 2-26-1999; (6) provisional patent application number 60/121,907, attorney docket number 25791.16, filed on 2-26-1999; (7) provisional patent application number 60/124,042, attorney docket number 25791.11, filed on 3-11-1999; (8) provisional patent application number 60/131,106, attorney docket number  
5 25791.23, filed on 4-26-1999; (9) provisional patent application number 60/137,998, attorney docket number 25791.17, filed on 6-7-1999; (10) provisional patent application number 60/143,039, attorney docket number 25791.26, filed on 7-9-1999; (11) provisional patent application number 60/146,203, attorney docket number 25791.25, filed on 7-29-1999; (12) provisional patent application number 60/154,047, attorney  
10 docket number 25791.29, filed on 9-16-1999; (13) provisional patent application number 60/159,082, attorney docket number 25791.34, filed on 10-12-1999; (14) provisional patent application number 60/159,039, attorney docket number 25791.36, filed on 10-12-1999; (15) provisional patent application number 60/159,033, attorney docket number 25791.37, filed on 10-12-1999; (16) provisional patent application  
15 number 60/162,671, attorney docket number 25791.27, filed on 11-01-1999.

#### Background of the Invention

This invention relates generally to wellbore casings, and in particular to wellbore casings that are formed using expandable tubing.

Conventionally, when a wellbore is created, a number of casings are installed in  
20 the borehole to prevent collapse of the borehole wall and to prevent undesired outflow of drilling fluid into the formation or inflow of fluid from the formation into the borehole. The borehole is drilled in intervals whereby a casing which is to be installed in a lower borehole interval is lowered through a previously installed casing of an upper borehole interval. As a consequence of this procedure the casing of the lower interval is of  
25 smaller diameter than the casing of the upper interval. Thus, the casings are in a nested arrangement with casing diameters decreasing in downward direction. Cement annuli are provided between the outer surfaces of the casings and the borehole wall to seal the casings from the borehole wall. As a consequence of this nested arrangement a relatively large borehole diameter is required at the upper part of the wellbore. Such  
30 a large borehole diameter involves increased costs due to heavy casing handling equipment, large drill bits and increased volumes of drilling fluid and drill cuttings. Moreover, increased drilling rig time is involved due to required cement pumping, cement hardening, required equipment changes due to large variations in hole

diameters drilled in the course of the well, and the large volume of cuttings drilled and removed.

Conventionally, at the surface end of the wellbore, a wellhead is formed that typically includes a surface casing, a number of production and/or drilling spools, 5 valving, and a Christmas tree. Typically the wellhead further includes a concentric arrangement of casings including a production casing and one or more intermediate casings. The casings are typically supported using load bearing slips positioned above the ground. The conventional design and construction of wellheads is expensive and complex.

10 Conventionally, a wellbore casing cannot be formed during the drilling of a wellbore. Typically, the wellbore is drilled and then a wellbore casing is formed in the newly drilled section of the wellbore. This delays the completion of a well.

The present invention is directed to overcoming one or more of the limitations of the existing procedures for forming wellbores and wellheads.

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#### Summary

According to the present invention there is provided a method of coupling a tubular member to a preexisting structure, comprising:

positioning the tubular member in an overlapping relationship to the preexisting structure;

20

placing a mandrel within the tubular member;

sealing off an annular region within the tubular member above the mandrel by sealing a stationary member and sealing a non-stationary member;

pressurizing the annular region;

displacing the mandrel with respect to the tubular member; and

25

removing fluids within the tubular member that are displaced by the displacement of the mandrel by passing the removed fluids inside of the annular region.

Preferably, displacing the mandrel further comprises radially expanding and plastically deforming the tubular member.

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Preferably, the method further comprises lubricating an interface between the mandrel and the tubular member.

According to another aspect of the present invention there is provided an apparatus for coupling a tubular member to a preexisting structure, comprising:

- means for positioning the tubular member in an overlapping relationship to the preexisting structure;
- means for placing a mandrel within the tubular member;
- means for sealing off an annular region within the tubular member above the
- 5 mandrel by sealing a stationary member and sealing a non-stationary member;
- means for pressurizing the annular region;
- means for displacing the mandrel with respect to the tubular member; and
- means for removing fluids within the tubular member that are displaced by the displacement of the mandrel by passing the removed fluids inside of the annular
- 10 region.
- Preferably, the tubular member includes one or more sealing means coupled to the exterior surface of the tubular member.
- Preferably, the mandrel includes one or more sealing means coupled to the exterior surface of the mandrel, the sealing means adapted to seal the interface
- 15 between the mandrel and the tubular member.
- Preferably, the mandrel is heat treated.
- Preferably, the mandrel is expandable.
- Preferably, the mandrel comprises one or more materials selected from the group consisting of machine tool steel, ceramics, tungsten carbide, and titanium.
- 20 Preferably, the mandrel includes a conical surface.
- Preferably, the angle of attack of the conical surface ranges from 1 to 30 degrees.
- Preferably, the conical surface has a surface hardness ranging from 58 to 62 Rockwell C.
- 25 According to another aspect of the present invention there is provided an apparatus for radially expanding a tubular member, comprising:
- a first tubular member;
- a second tubular member positioned within the first tubular member;
- a third tubular member movably coupled to and positioned within the second
- 30 tubular member;
- a first annular sealing member for sealing an interface between the first and second tubular members;
- a second annular sealing member for sealing an interface between the second and third tubular members;

- a mandrel positioned within the first tubular member and coupled to an end of the third tubular member;
- an annular chamber defined by the first tubular member, the second tubular member, the third tubular member, the first annular sealing member, the second 5 annular sealing member, and the mandrel;
- a fluid passage defined by the third tubular member and the mandrel fluidically coupled to an interior region of the first tubular member below the mandrel; and
- an annular passage defined by the second tubular member and the third tubular member fluidically coupled to the annular chamber.
- 10 Preferably, the mandrel is heat treated.
- Preferably, the mandrel is expandable.
- Preferably, the mandrel comprises one or more materials selected from the group consisting of machine tool steel, ceramics, tungsten carbide, and titanium.
- Preferably, the mandrel includes a conical surface.
- 15 Preferably, the angle of attack of the conical surface ranges from 1 to 30 degrees.
- Preferably, the conical surface has a surface hardness ranging from 58 to 62 Rockwell C.
- According to another aspect of the present invention there is provided an 20 apparatus, comprising:
- a first tubular member; and
- a second tubular member coupled to the first tubular member in an overlapping relationship to the first tubular member;
- 25 a mandrel within the second tubular member;
- an annular region within the second tubular member above the mandrel comprising a sealing mechanism coupled to a stationary member and a non-stationary member, the annular region adapted to be pressurized;
- the mandrel adapted to be displaced with respect to the second tubular member; and
- 30 a mechanism adapted to remove fluids within the second tubular member that are displaced by the displacement of the mandrel by passing the removed fluids inside of the annular region.
- Preferably, the first tubular member includes one or more sealing members coupled to the exterior surface of the first tubular member.

Preferably, the second tubular member includes one or more sealing members coupled to the exterior surface of the second tubular member.

Preferably, the mandrel includes one or more sealing members coupled to the exterior surface of the mandrel, the sealing members adapted to seal the interface

- 5 between the mandrel and the second tubular member.

Preferably, the mandrel is heat treated.

Preferably, the mandrel is expandable.

Preferably, the mandrel comprises one or more materials selected from the group consisting of machine tool steel, ceramics, tungsten carbide, and titanium.

- 10 Preferably, the mandrel includes a conical surface.

Preferably, the angle of attack of the conical surface ranges from 1 to 30 degrees.

Preferably, the conical surface has a surface hardness ranging from 58 to 62 Rockwell C.

15 Brief Description of the Drawings

FIG. 1a is a fragmentary cross-section illustration of an apparatus and method for expanding tubular members.

FIG. 1b is another fragmentary cross-sectional illustration of the apparatus of FIG. 1a.

- 20 FIG. 1c is another fragmentary cross-sectional illustration of the apparatus of FIG. 1a.

FIG. 2a is a fragmentary cross-section illustration of an apparatus and method for expanding tubular members.

- 25 FIG. 2b is another fragmentary cross-sectional illustration of the apparatus of FIG. 2a.

FIG. 2c is another fragmentary cross-sectional illustration of the apparatus of FIG. 2a.

FIG. 2d is another fragmentary cross-sectional illustration of the apparatus of FIG. 2a.

- 30 FIG. 2e is another fragmentary cross-sectional illustration of the apparatus of FIG. 2a.

Detailed Description

- Referring now to FIGS. 1a, 1b and 1c, an apparatus 100 for expanding a tubular member will be described. The apparatus 100 includes a support member 105, a packer 110, a first fluid conduit 115, an annular fluid passage 120, fluid inlets 125, an

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annular seal 130, a second fluid conduit 135, a fluid passage 140, a mandrel 145, a mandrel launcher 150, a tubular member 155, slips 160, and seals 165. The apparatus 100 is used to radially expand the tubular member 155. In this manner, the apparatus 100 may be used to form a wellbore casing, line a wellbore casing, form a pipeline, line 5 a pipeline, form a structural support member, or repair a wellbore casing, pipeline or structural support member. The apparatus 100 is used to clad at least a portion of the tubular member 155 onto a preexisting tubular member.

The support member 105 is preferably coupled to the packer 110 and the mandrel launcher 150. The support member 105 preferably is a tubular member 10 10 fabricated from any number of conventional commercially available materials such as, for example, oilfield country tubular goods, low alloy steel, carbon steel, or stainless steel. The support member 105 is preferably selected to fit through a preexisting section of wellbore casing 170. In this manner, the apparatus 100 may be positioned within the wellbore casing 170. The support member 105 is releasably coupled to the 15 mandrel launcher 150. In this manner, the support member 105 may be decoupled from the mandrel launcher 150 upon the completion of an extrusion operation.

The packer 110 is coupled to the support member 105 and the first fluid conduit 115. The packer 110 preferably provides a fluid seal between the outside surface of the first fluid conduit 115 and the inside surface of the support member 105. In this 20 manner, the packer 110 preferably seals off and, in combination with the support member 105, first fluid conduit 115, second fluid conduit 135, and mandrel 145, defines an annular chamber 175. The packer 110 may be any number of conventional commercially available packers modified in accordance with the teachings of the present disclosure. The packer 110 is an RTTS packer available from Halliburton 25 Energy Services in order to optimally provide high load and pressure containment capacity while also allowing the packer to be set and unset multiple times without having to pull the packer out of the wellbore.

The first fluid conduit 115 is coupled to the packer 110 and the annular seal 130. The first fluid conduit 115 preferably is an annular member fabricated from any 30 number of conventional commercially available materials such as, for example, oilfield country tubular goods, low alloy steel, carbon steel, or stainless steel. The first fluid conduit 115 includes one or more fluid inlets 125 for conveying fluidic materials from the annular fluid passage 120 into the chamber 175.

The annular fluid passage 120 is defined by and positioned between the interior surface of the first fluid conduit 115 and the interior surface of the second fluid conduit 135. The annular fluid passage 120 is preferably adapted to convey fluidic materials such as cement, water, epoxy, lubricants, and slag mix at operating pressures and flow rates ranging from about 0 to 11356.24 litres/minute (0 to 3,000 gallons/minute) and 0 to 620.528 bar (0 to 9,000 psi) in order to optimally provide flow rates and operational pressures for the radial expansion process.

The fluid inlets 125 are positioned in an end portion of the first fluid conduit 115. The fluid inlets 125 preferably are adapted to convey fluidic materials such as cement, water, epoxy, lubricants, and slag mix at operating pressures and flow rates ranging from about 0 to 620.528 bar (0 to 9,000 psi) and 0 to 11356.24 litres/minute (0 to 3,000 gallons/minute) in order to optimally provide flow rates and operational pressures for the radial expansion process.

The annular seal 130 is coupled to the first fluid conduit 115 and the second fluid conduit 135. The annular seal 130 preferably provides a fluid seal between the interior surface of the first fluid conduit 115 and the exterior surface of the second fluid conduit 135. The annular seal 130 preferably provides a fluid seal between the interior surface of the first fluid conduit 115 and the exterior surface of the second fluid conduit 135 during relative axial motion of the first fluid conduit 115 and the second fluid conduit 135. The annular seal 130 may be any number of conventional commercially available seals such as, for example, O-rings, Polypak<sup>(RTM)</sup> seals, or metal spring energized seals. The annular seal 130 is a Polypak<sup>(RTM)</sup> seal available from Parker Seals.

The second fluid conduit 135 is coupled to the annular seal 130 and the mandrel 145. The second fluid conduit preferably is a tubular member fabricated from any number of conventional commercially available materials such as, for example, coiled tubing, oilfield country tubular goods, low alloy steel, stainless steel, or low carbon steel. The second fluid conduit 135 is adapted to convey fluidic materials such as cement, water, epoxy, lubricants, and slag mix at operating pressures and flow rates ranging from about 0 to 620.528 bar (0 to 9,000 psi) and 0 to 11356.24 litres/minute (0 to 3,000 gallons/minute) in order to optimally provide flow rates and operational pressures for the radial expansion process.

The fluid passage 140 is coupled to the second fluid conduit 135 and the mandrel 145. The fluid passage 140 is adapted to convey fluidic materials such as

- 20 46 00
- cement, water, epoxy, lubricants, and slag mix at operating pressures and flow rates ranging from about 0 to 620.528 bar (0 to 9,000 psi) and 0 to 11356.24 litres/minute (0 to 3,000 gallons/minute) in order to optimally provide flow rates and operational pressures for the radial expansion process.
- 5       The mandrel 145 is coupled to the second fluid conduit 135 and the mandrel launcher 150. The mandrel 145 preferably is an annular member having a conic section fabricated from any number of conventional commercially available materials such as, for example, machine tool steel, ceramics, tungsten carbide, titanium or other high strength alloys. The angle of the conic section of the mandrel 145 ranges from  
10      about 1 to 30 degrees in order to optimally expand the mandrel launcher 150 and tubular member 155 in the radial direction. The surface of the conic section ranges from about 58 to 62 Rockwell C in order to optimally provide high yield strength. The expansion cone 145 is heat treated in order to optimally provide a hard outer surface and a resilient interior body in order to optimally provide abrasion resistance and  
15      fracture toughness. Alternatively, the mandrel 145 is expandible in order to further optimally augment the radial expansion process.
- The mandrel launcher 150 is coupled to the support member 105, the mandrel 145, and the tubular member 155. The mandrel launcher 150 preferably is a tubular member having a variable cross-section and a reduced wall thickness in order to  
20      facilitate the radial expansion process. The cross-sectional area of the mandrel launcher 150 at one end is adapted to mate with the mandrel 145, and at the other end, the cross-sectional area of the mandrel launcher 150 is adapted to match the cross-sectional area of the tubular member 155. The wall thickness of the mandrel launcher 150 ranges from about 50 to 100 % of the wall thickness of the tubular member 155 in  
25      order to facilitate the initiation of the radial expansion process.
- The mandrel launcher 150 may be fabricated from any number of conventional commercially available materials such as, for example, oilfield country tubular goods, low allow steel, stainless steel, or carbon steel. The mandrel launcher 150 is fabricated from oilfield country tubular goods having higher strength but lower wall thickness than  
30      the tubular member 155 in order to optimally match the burst strength of the tubular member 155. The mandrel launcher 150 is removably coupled to the tubular member 155. In this manner, the mandrel launcher 150 may be removed from the wellbore 180 upon the completion of an extrusion operation.

Alternatively, the support member 105 and the mandrel launcher 150 are integrally formed. The support member 105 preferably terminates above the top of the packer 110. The fluid conduits 115 and/or 135 provide structural support for the apparatus 100, using the packer 110 to couple together the elements of the apparatus

5 100. During the radial expansion process, the packer 110 may be unset and reset, after the slips 160 have anchored the tubular member 155 to the previous casing 170, within the tubular member 155, between radial expansion operations. In this manner, the packer 110 is moved downhole and the apparatus 100 is re-stroked.

The tubular member 155 is coupled to the mandrel launcher, the slips 160 and  
10 the seals 165. The tubular member 155 preferably is a tubular member fabricated from any number of conventional commercially available materials such as, for example, low alloy steel, carbon steel, stainless steel, or oilfield country tubular goods. The tubular member 155 is fabricated from oilfield country tubular goods.

The slips 160 are coupled to the outside surface of the tubular member 155.  
15 The slips 160 preferably are adapted to couple to the interior walls of a casing, pipeline or other structure upon the radial expansion of the tubular member 155. In this manner, the slips 160 provide structural support for the expanded tubular member 155. The slips 160 may be any number of conventional commercially available slips such as, for example, RTTS packer tungsten carbide slips, RTTS packer wicker type  
20 mechanical slips or Model 3L retrievable bridge plug tungsten carbide upper mechanical slips. The slips 160 are RTTS packer tungsten carbide mechanical slips available from Halliburton Energy Services. The slips 160 are adapted to support axial forces ranging from about 0 to 3336.2 kN (0 to 750,000 lbf).

The seals 165 are coupled to the outside surface of the tubular member 155.  
25 The seals 165 preferably provide a fluidic seal between the outside surface of the expanded tubular member 155 and the interior walls of a casing, pipeline or other structure upon the radial expansion of the tubular member 155. In this manner, the seals 165 provide a fluidic seal for the expanded tubular member 155. The seals 165 may be any number of conventional commercially available seals such as, for example,  
30 nitrile rubber, lead, Aflas<sup>(RTM)</sup> rubber, Teflon<sup>(RTM)</sup>, epoxy, or other elastomers. The seals 165 are rubber seals available from numerous commercial vendors in order to optimally provide pressure sealing and load bearing capacity.

During operation of the apparatus 100, the apparatus 100 is preferably lowered into a wellbore 180 having a preexisting section of wellbore casing 170. The apparatus

100 is positioned with at least a portion of the tubular member 155 overlapping with a portion of the wellbore casing 170. In this manner, the radial expansion of the tubular member 155 will preferably cause the outside surface of the expanded tubular member 155 to couple with the inside surface of the wellbore casing 170. The radial expansion 5 of the tubular member 155 will also cause the slips 160 and seals 165 to engage with the interior surface of the wellbore casing 170. In this manner, the expanded tubular member 155 is provided with enhanced structural support by the slips 160 and an enhanced fluid seal by the seals 165.

As illustrated in FIG. 1b, after placement of the apparatus 100 in an overlapping 10 relationship with the wellbore casing 170, a fluidic material 185 is preferably pumped into the chamber 175 using the fluid passage 120 and the inlet passages 125. The fluidic material is pumped into the chamber 175 at operating pressures and flow rates ranging from about 0 to 620.528 bar (0 to 9,000 psi) and 0 to 11356.24 litres/minute (0 15 to 3,000 gallons/minute) in order to optimally provide flow rates and operational pressures for the radial expansion process. The pumped fluidic material 185 increase the operating pressure within the chamber 175. The increased operating pressure in the chamber 175 then causes the mandrel 145 to extrude the mandrel launcher 150 and tubular member 155 off of the face of the mandrel 145. The extrusion of the mandrel launcher 150 and tubular member 155 off of the face of the mandrel 145 20 causes the mandrel launcher 150 and tubular member 155 to expand in the radial direction. Continued pumping of the fluidic material 185 preferably causes the entire length of the tubular member 155 to expand in the radial direction.

The pumping rate and pressure of the fluidic material 185 is reduced during the latter stages of the extrusion process in order to minimize shock to the apparatus 100. 25 The apparatus 100 includes shock absorbers for absorbing the shock caused by the completion of the extrusion process.

The extrusion process causes the mandrel 145 to move in an axial direction 185. During the axial movement of the mandrel, the fluid passage 140 conveys fluidic material 190 displaced by the moving mandrel 145 out of the wellbore 180. In this 30 manner, the operational efficiency and speed of the extrusion process is enhanced.

The extrusion process includes the injection of a hardenable fluidic material into the annular region between the tubular member 155 and the bore hole 180. In this manner, a hardened sealing layer is provided between the expanded tubular member 155 and the interior walls of the wellbore 180.

As illustrated in FIG. 1c, upon the completion of the extrusion process, the support member 105, packer 110, first fluid conduit 115, annular seal 130, second fluid conduit 135, mandrel 145, and mandrel launcher 150 are moved from the wellbore 180.

Alternatively, the apparatus 100 is used to repair a preexisting wellbore casing 5 170 or pipeline. Both ends of the tubular member 155 preferably include slips 160 and seals 165.

Alternatively, the apparatus 100 is used to form a tubular structural support for a building or offshore structure.

Referring now to FIGS. 2a, 2b, 2c, 2d, and 2e, an apparatus 200 for expanding 10 a tubular member will be described. The apparatus 200 includes a support member 205, a mandrel launcher 210, a mandrel 215, a first fluid passage 220, a tubular member 225, slips 230, seals 235, a shoe 240, and a second fluid passage 245. The apparatus 200 is used to radially expand the mandrel launcher 210 and tubular member 225. In this manner, the apparatus 200 may be used to form a wellbore 15 casing, line a wellbore casing, form a pipeline, line a pipeline, form a structural support member, or repair a wellbore casing, pipeline or structural support member.. The apparatus 200 is used to clad at least a portion of the tubular member 225 onto a preexisting structural member.

The support member 205 is preferably coupled to the mandrel launcher 210. 20 The support member 205 preferably is a tubular member fabricated from any number of conventional commercially available materials such as, for example, oilfield country tubular goods, low alloy steel, carbon steel, or stainless steel. The support member 205, the mandrel launcher 210, the tubular member 225, and the shoe 240 are preferably selected to fit through a preexisting section of wellbore casing 270. In this 25 manner, the apparatus 200 may be positioned within the wellbore casing 270. The support member 205 is releasably coupled to the mandrel launcher 210. In this manner, the support member 205 may be decoupled from the mandrel launcher 210 upon the completion of an extrusion operation.

The mandrel launcher 210 is coupled to the support member 205 and the 30 tubular member 225. The mandrel launcher 210 preferably is a tubular member having a variable cross-section and a reduced wall thickness in order to facilitate the radial expansion process. The cross-sectional area of the mandrel launcher 210 at one end is adapted to mate with the mandrel 215, and at the other end, the cross-sectional area of the mandrel launcher 210 is adapted to match the cross-sectional area of the tubular

member 225. The wall thickness of the mandrel launcher 210 ranges from about 50 to 100 % of the wall thickness of the tubular member 225 in order to facilitate the initiation of the radial expansion process.

The mandrel launcher 210 may be fabricated from any number of conventional commercially available materials such as, for example, oilfield country tubular goods, low allow steel, stainless steel, or carbon steel. The mandrel launcher 210 is fabricated from oilfield country tubular goods having higher strength but lower wall thickness than the tubular member 225 in order to optimally match the burst strength of the tubular member 225. The mandrel launcher 210 is removably coupled to the tubular member 225. In this manner, the mandrel launcher 210 may be removed from the wellbore 260 upon the completion of an extrusion operation.

The mandrel 215 is coupled to the mandrel launcher 210. The mandrel 215 preferably is an annular member having a conic section fabricated from any number of conventional commercially available materials such as, for example, machine tool steel, ceramics, tungsten carbide, titanium or other high strength alloys. The angle of the conic section of the mandrel 215 ranges from about 0 to 30 degrees in order to optimally expand the mandrel launcher 210 and the tubular member 225 in the radial direction. The surface of the conic section ranges from about 58 to 62 Rockwell C in order to optimally provide high yield strength. The expansion cone 215 is heat treated in order to optimally provide a hard outer surface and a resilient interior body in order to optimally provide abrasion resistance and fracture toughness. Alternatively, the mandrel 215 is expandible in order to further optimally augment the radial expansion process.

The fluid passage 220 is positioned within the mandrel 215. The fluid passage 220 is preferably adapted to convey fluidic materials such as cement, water, epoxy, lubricants, and slag mix at operating pressures and flow rates ranging from about 0 to 620.528 bar (0 to 9,000 psi) and 0 to 11356.24 litres/minute (0 to 3,000) gallons/minute in order to optimally provide flow rates and operational pressures for the radial expansion process. The fluid passage 220 preferably includes an inlet 265 adapted to receive a plug, or other similar device. In this manner, the interior chamber 270 above the mandrel 215 may be fluidically isolated from the interior chamber 275 below the mandrel 215.

The tubular member 225 is coupled to the mandrel launcher 210, the slips 230 and the seals 235. The tubular member 225 preferably is a tubular member fabricated

from any number of conventional commercially available materials such as, for example, low alloy steel, carbon steel, stainless steel, or oilfield country tubular goods. The tubular member 225 is fabricated from oilfield country tubular goods.

The slips 230 are coupled to the outside surface of the tubular member 225.

- 5 The slips 230 preferably are adapted to couple to the interior walls of a casing, pipeline or other structure upon the radial expansion of the tubular member 225. In this manner, the slips 230 provide structural support for the expanded tubular member 225. The slips 230 may be any number of conventional commercially available slips such as, for example, RTTS packer tungsten carbide mechanical slips, RTTS packer wicker 10 type mechanical slips, or Model 3L retrievable bridge plug tungsten carbide upper mechanical slips. The slips 230 are adapted to support axial forces ranging from about 0 to 3336.2 kN (0 to 750,000 lbf).

The seals 235 are coupled to the outside surface of the tubular member 225.

- 15 The seals 235 preferably provide a fluidic seal between the outside surface of the expanded tubular member 225 and the interior walls of a casing, pipeline or other structure upon the radial expansion of the tubular member 225. In this manner, the seals 235 provide a fluidic seal for the expanded tubular member 225. The seals 235 may be any number of conventional commercially available seals such as, for example, nitrile rubber, lead, Aflas<sup>(RTM)</sup> rubber, Teflon<sup>(RTM)</sup>, epoxy or other elastomers. The seals 20 235 are conventional rubber seals available from various commercial vendors in order to optimally provide pressure sealing and load bearing capacity.

The shoe 240 is coupled to the tubular member 225. The shoe 240 preferably is a substantially tubular member having a fluid passage 245 for conveying fluidic materials from the chamber 275 to the annular region 270 outside of the apparatus

- 25 200. The shoe 240 may be any number of conventional commercially available shoes such as, for example, a Super Seal<sup>(RTM)</sup> II float shoe, a Super Seal<sup>(RTM)</sup> II Down-Jet float shoe, or a guide shoe with a sealing sleeve for a latch down plug modified in accordance with the teachings of the present disclosure. The shoe 240 is an aluminum down-jet guide shoe with a sealing sleeve for a latch down plug, available from 30 Halliburton Energy Services, modified in accordance with the teachings of the present disclosure, in order to optimally guide the tubular member 225 in the wellbore, optimally provide a fluidic seal between the interior and exterior diameters of the overlapping joint between the tubular members, and optimally facilitate the complete drilling out of

200-604

the shoe and plug upon the completion of the cementing and radial expansion operations.

During operation of the apparatus 200, the apparatus 200 is preferably lowered into a wellbore 260 having a preexisting section of wellbore casing 275. The apparatus 5 200 is positioned with at least a portion of the tubular member 225 overlapping with a portion of the wellbore casing 275. In this manner, the radial expansion of the tubular member 225 will preferably cause the outside surface of the expanded tubular member 225 to couple with the inside surface of the wellbore casing 275. The radial expansion of the tubular member 225 will also cause the slips 230 and seals 235 to engage with 10 the interior surface of the wellbore casing 275. In this manner, the expanded tubular member 225 is provided with enhanced structural support by the slips 230 and an enhanced fluid seal by the seals 235.

As illustrated in FIG. 2b, after placement of the apparatus 200 in an overlapping relationship with the wellbore casing 275, a fluidic material 280 is preferably pumped 15 into the chamber 270. The fluidic material 280 then passes through the fluid passage 220 into the chamber 275. The fluidic material 280 then passes out of the chamber 275, through the fluid passage 245, and into the annular region 270. The fluidic material 280 is pumped into the chamber 270 at operating pressures and flow rates ranging from about 0 to 620.528 bar (0 to 9,000 psi) and 0 to 11356.24 litres/minute (0 20 to 3,000 gallons/minute) in order to optimally provide flow rates and operational pressures for the radial expansion process. The fluidic material 280 is a hardenable fluidic sealing material in order to form a hardened outer annular member around the expanded tubular member 225.

As illustrated in FIG. 2c, at some later point in the process, a ball 285, plug or 25 other similar device, is introduced into the pumped fluidic material 280. The ball 285 mates with and seals off the inlet 265 of the fluid passage 220. In this manner, the chamber 270 is fluidically isolated from the chamber 275.

As illustrated in FIG. 2d, after placement of the ball 285 in the inlet 265 of the fluid passage 220, a fluidic material 290 is pumped into the chamber 270. The fluidic 30 material is preferably pumped into the chamber 270 at operating pressures and flow rates ranging from about 0 to 620.528 bar (0 to 9,000 psi) and 0 to 11356.24 litres/minute (0 to 3,000 gallons/minute) in order to provide optimal operating efficiency. The fluidic material 290 may be any number of conventional commercially available materials such as, for example, water, drilling mud, cement, epoxy, or slag mix. The

fluidic material 290 is a non-hardenable fluidic material in order to maximize operational efficiency.

Continued pumping of the fluidic material 290 increases fluidic material 280 increases the operating pressure within the chamber 270. The increased operating 5 pressure in the chamber 270 then causes the mandrel 215 to extrude the mandrel launcher 210 and tubular member 225 off of the conical face of the mandrel 215. The extrusion of the mandrel launcher 210 and tubular member 225 off of the conical face of the mandrel 215 causes the mandrel launcher 210 and tubular member 225 to expand in the radial direction. Continued pumping of the fluidic material 290 preferably 10 causes the entire length of the tubular member 225 to expand in the radial direction.

The pumping rate and pressure of the fluidic material 290 is reduced during the latter stages of the extrusion process in order to minimize shock to the apparatus 200. The apparatus 200 includes shock absorbers for absorbing the shock caused by the completion of the extrusion process. The extrusion process causes the mandrel 215 15 to move in an axial direction 290.

As illustrated in FIG. 2e, upon the completion of the extrusion process, the support member 205, packer 210, first fluid conduit 215, annular seal 230, second fluid conduit 235, mandrel 245, and mandrel launcher 250 are removed from the wellbore 20. The resulting new section of wellbore casing includes the preexisting wellbore 25 casing 275, the expanded tubular member 225, the slips 230, the seals 235, the shoe 240, and an outer annular layer 300 of hardened fluidic material.

Alternatively, the apparatus 200 is used to repair a preexisting wellbore casing or pipeline. Both ends of the tubular member 255 preferably include slips 260 and seals 265.

25 Alternatively, the apparatus 200 is used to form a tubular structural support for a building or offshore structure.

The tubular members 105 and 225; shoes 240; expansion cone launchers 150 and 210; and expansion cones 145 and 215 are provided substantially as described in one or more of the following U.S. patents and applications: (1) utility patent number 30 6,328,113, attorney docket number 25791.9.02, filed on 11-15-1999, which claimed the benefit of the filing date of provisional patent application number 60/108,558, attorney docket number 25791.9, filed on 11-16-1998; (2) utility patent number 6,497,289, attorney docket number 25791.3.02, filed on 12-3-1999, which claimed the benefit of the filing date of provisional patent application number 60/111,293, attorney docket

number 25791.3, filed on 12-7-1998; (3) utility patent application number 09/502,350, attorney docket number 25791.8.02, filed on 2-10-2000, which claimed the benefit of the filing date of provisional patent application number 60/119,611, attorney docket number 25791.8, filed on 2-11-1999; (4) provisional patent application number 5 60/121,702, attorney docket number 25791.7, filed on 2-25-1999; (5) provisional patent application number 60/121,841, attorney docket number 25791.12, filed on 2-26-1999; (6) provisional patent application number 60/121,907, attorney docket number 25791.16, filed on 2-26-1999; (7) provisional patent application number 60/124,042, attorney docket number 25791.11, filed on 3-11-1999; (8) provisional patent application 10 number 60/131,106, attorney docket number 25791.23, filed on 4-26-1999; (9) provisional patent application number 60/137,998, attorney docket number 25791.17, filed on 6-7-1999; (10) provisional patent application number 60/143,039, attorney docket number 25791.26, filed on 7-9-1999; (11) provisional patent application number 15 60/146,203, attorney docket number 25791.25, filed on 7-29-1999; (12) provisional patent application number 60/154,047, attorney docket number 25791.29, filed on 9-16-1999; (13) provisional patent application number 60/159,082, attorney docket number 25791.34, filed on 10-12-1999; (14) provisional patent application number 60/159,039, attorney docket number 25791.36, filed on 10-12-1999; (15) provisional patent application number 60/159,033, attorney docket number 25791.37, filed on 10-20 12-1999; (16) provisional patent application number 60/162,671, attorney docket number 25791.27, filed on 11-01-1999.

Although illustrative aspects of the invention have been shown and described, a wide range of modification, changes and substitution is contemplated in the foregoing disclosure. In some instances, some features of the present invention may be 25 employed without a corresponding use of the other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention.

CLAIMS

1. A method of coupling a tubular member to a preexisting structure, comprising:
  - 5 positioning the tubular member in an overlapping relationship to the preexisting structure;
  - placing a mandrel within the tubular member;
  - sealing off an annular region within the tubular member above the mandrel by sealing a stationary member and sealing a non-stationary member;
  - pressurizing the annular region;
- 10 displacing the mandrel with respect to the tubular member; and
- removing fluids within the tubular member that are displaced by the displacement of the mandrel by passing the removed fluids inside of the annular region.
- 15 2. An apparatus for coupling a tubular member to a preexisting structure, comprising:
  - means for positioning the tubular member in an overlapping relationship to the preexisting structure;
  - means for placing a mandrel within the tubular member;
- 20 means for sealing off an annular region within the tubular member above the mandrel by sealing a stationary member and sealing a non-stationary member;
- means for pressurizing the annular region;
- means for displacing the mandrel with respect to the tubular member; and
- 25 means for removing fluids within the tubular member that are displaced by the displacement of the mandrel by passing the removed fluids inside of the annular region.
3. An apparatus for radially expanding a tubular member, comprising:
  - a first tubular member;
  - 30 a second tubular member positioned within the first tubular member;
  - a third tubular member movably coupled to and positioned within the second tubular member;
  - a first annular sealing member for sealing an interface between the first and second tubular members;

- a second annular sealing member for sealing an interface between the second and third tubular members;
- a mandrel positioned within the first tubular member and coupled to an end of the third tubular member;
- 5 an annular chamber defined by the first tubular member, the second tubular member, the third tubular member, the first annular sealing member, the second annular sealing member, and the mandrel;
- a fluid passage defined by the third tubular member and the mandrel fluidically coupled to an interior region of the first tubular member below the mandrel; and
- 10 10 an annular passage defined by the second tubular member and the third tubular member fluidically coupled to the annular chamber.
4. An apparatus, comprising:
- a first tubular member; and
- 15 15 a second tubular member coupled to the first tubular member in an overlapping relationship to the first tubular member;
- a mandrel within the second tubular member;
- an annular region within the second tubular member above the mandrel comprising a sealing mechanism coupled to a stationary member and a non-stationary 20 member, the annular region adapted to be pressurized;
- the mandrel adapted to be displaced with respect to the second tubular member; and
- 25 25 a mechanism adapted to remove fluids within the second tubular member that are displaced by the displacement of the mandrel by passing the removed fluids inside of the annular region.
5. The method of claim 1, wherein displacing the mandrel further comprises radially expanding and plastically deforming the tubular member.
- 30 6. The method of claim 1, further comprising lubricating an interface between the mandrel and the tubular member.
7. The apparatus of claim 2, wherein the tubular member includes one or more sealing means coupled to the exterior surface of the tubular member.

8. The apparatus of claim 2, wherein the mandrel includes one or more sealing means coupled to the exterior surface of the mandrel, the sealing means adapted to seal the interface between the mandrel and the tubular member.

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9. The apparatus of claim 2, wherein the mandrel is heat treated.

10. The apparatus of claim 2, wherein the mandrel is expandable.

10 11. The apparatus of claim 2, wherein the mandrel comprises one or more materials selected from the group consisting of machine tool steel, ceramics, tungsten carbide, and titanium.

12. The apparatus of claim 2, wherein the mandrel includes a conical surface.

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13. The apparatus of claim 12, wherein the angle of attack of the conical surface ranges from 1 to 30 degrees.

14. The apparatus of claim 12, wherein the conical surface has a surface hardness 20 ranging from 58 to 62 Rockwell C.

15. The apparatus of claim 3, wherein the mandrel is heat treated.

16. The apparatus of claim 3, wherein the mandrel is expandable.

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17. The apparatus of claim 3, wherein the mandrel comprises one or more materials selected from the group consisting of machine tool steel, ceramics, tungsten carbide, and titanium.

30 18. The apparatus of claim 3, wherein the mandrel includes a conical surface.

19. The apparatus of claim 18, wherein the angle of attack of the conical surface ranges from 1 to 30 degrees.

20. The apparatus of claim 18, wherein the conical surface has a surface hardness ranging from 58 to 62 Rockwell C.
21. The apparatus of claim 4, wherein the first tubular member includes one or more sealing members coupled to the exterior surface of the first tubular member.
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22. The apparatus of claim 4, wherein the second tubular member includes one or more sealing members coupled to the exterior surface of the second tubular member.
- 10 23. The apparatus of claim 4, wherein the mandrel includes one or more sealing members coupled to the exterior surface of the mandrel, the sealing members adapted to seal the interface between the mandrel and the second tubular member.
- 15 24. The apparatus of claim 4, wherein the mandrel is heat treated.
25. The apparatus of claim 4, wherein the mandrel is expandable.
- 20 26. The apparatus of claim 4, wherein the mandrel comprises one or more materials selected from the group consisting of machine tool steel, ceramics, tungsten carbide, and titanium.
27. The apparatus of claim 4, wherein the mandrel includes a conical surface.
28. The apparatus of claim 27, wherein the angle of attack of the conical surface ranges from 1 to 30 degrees.
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29. The apparatus of claim 27, wherein the conical surface has a surface hardness ranging from 58 to 62 Rockwell C.

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